Poly Ether Ether Ketone (PEEK) Applications in Prosthodontics – A Review "Peek into PEEK at Peak"

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ABSTRACT

BACKGROUND

Life is becoming more convenient as advancement in materials has been taking place since the beginning of human history. The increased demand of aesthetics in day to day life and on the other hand disadvantages of the existing materials, clinicians are shifting their paradigms towards metal free restorations. Various researches are going on to identify the ideal restorative material with all the improved mechanical and physical qualities. Advances in the field of dental materials are providing promising results but each material is falling short of being an ideal one. One such material is biomaterials. Biomaterials are mainly used in medical sciences to replace or augment a natural function. Biomaterials are widely used in dentistry, they are divided into four categories metal, composites, polymer and resins. Biomaterials are considered as materials which replace the defects by either replacements or repair. Presently Poly-Ether Ether Ketone (PEEK) is a semi crystalline, synthetic, aromatic, thermoplastic material. Previously, it was used for industrial purposes but due to its excellent properties and biocompatibility, it has been used in medicine and dentistry. There are various applications of PEEK in dentistry such as orthodontic wires and brackets which are made from it to achieve aesthetics and strength. In endodontics PEEK posts and PEEK endocrowns are used when extensive tooth structure loss occurs, even due to its aesthetic property, it is used for anterior restorations. PEEK is a synthetic polymer and is greyish in colour which has a monomer unit of ether ether ketone. In prosthodontics, aesthetics plays an important role. Therefore, PEEK is considered as an alternative option to conventional dental materials because of its aesthetics and it being a scientifically approved material. In prosthodontics, it can be used in removable partial dentures, fixed partial dentures, dental implants and abutments, implant crowns as well as for restoring the maxillofacial defects. This review article describes the various applications of PEEK in prosthodontics in detail.

KEY WORDS

Biomaterials, Prosthodontics, PEEK Implants, Prosthesis, Surface Treatment, Dental Material

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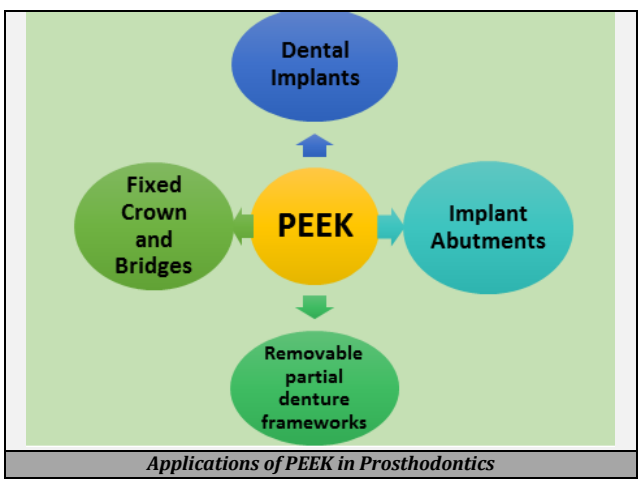
BACKGROUND

In recent years, there are various biomaterials which are being synthesised which are used for improving performance in medical field. In dentistry, metal free restorations are gaining popularity. PEEK is one of them, because of its excellent properties it has potential uses in dentistry. In early 1980s PEEK was first commercialised for industrial purposes like piston parts, aircrafts, turbine blades, compressor plate valves and cable insulation. Later in 1998 it was proposed for biomedical applications by Invibio Ltd (Thornton-Cleveleys, UK).[1] Titanium implants and its alloy have been introduced by Branemark. But the titanium has clinical disadvantage of metal hypersensitivity, high modulus of elasticity, surface degradation leading to peri implantitis, metallic colour which hampers the aesthetics. Recently PEEK is one of the scientifically approved feasible material which restores the missing orofacial structures. PEEK has several applications like in implantology, removable denture framework, fixed partial dentures and orthodontic wires.[2] This review article summarises the properties and applications of PEEK in prosthodontics.



Applications of PEEK in Prosthodontics

STRUCTURES AND PROPERTIES OF PEEK

PEEK is a synthetic polymer and is greyish in colour which has a monomer unit of ether ether ketone. Mainly PEEK is synthesised at 300 ˚C and reaction occurs between 4, 4′-difluoro benzophenone and the sodium salt of hydroquinone in a polar solvent. PEEK has a melting point of 335˚ C and is semi-crystalline thermoplastic in nature, modification can be done by addition of functionalised monomers or by chemical process such as nitration and amination. PEEK can be sterilised with heat sterilisation because it is resistant to deterioration.[3]

PEEK has excellent properties. It is the most biocompatible and has less Young's modulus of elasticity (3 – 4 GPa) which is close to the human bone. Properties of PEEK is alter simply by addition of various materials, as elastic modulus can be increased by incorporation of carbon fibres.[4] Branemark introduced the use of titanium and its alloys for dental implants. This titanium alloys have significantly high elastic modulus resulting in intense stress shielding and non-success.[5] The carbon reinforced PEEK modulus of elasticity is also similar to dentin and cortical bone so the polymer could manifest lower stress shielding in contrast to titanium implants.[6] Moreover PEEK has excellent thermal properties, superior wear resistance, inertness, corrosion resistance, high strength and modulus of elasticity is analogous to enamel, dentin and cortical bone. Radiographic radiolucency and low density make it acceptable for medical applications.[7] PEEK components are manufactured by rapid prototyping, CAD CAM (Computer-aided design and Computer-aided manufacturing) milling or by injection, extrusion and compression moulding techniques.[8]

PEEK AS AN IMPLANT MATERIAL

Dental implants are the most feasible treatment option for replacement of missing teeth. Titanium implants are still most commonly used in dentistry because of its high success rate, biocompatibility, corrosion resistance and sufficient mechanical properties. In spite of various advantages of titanium material and its alloy, there are certain disadvantages such as resorption of bone around implant, surface deterioration (peri implantitis), over sensitivity reactions and allergic potential. To overcome the pitfalls of the titanium implants, PEEK implants with its modifications can be used clinically.[9]

According to Wolff's Law, when implant is placed the remodelling of bone takes place according to the load that has been applied to it. Modifications to PEEK can exhibit lower stress shielding as compared to titanium. PEEK is not widely used in implantology because it is still unspecified whether there is any difference in resorption of bone between PEEK and titanium. Sarot et al suggests that there is no difference between the stress distributions. Various studies also suggest likeness between the osseointegration of PEEK and titanium implants. But still the long-term success rate of unmodified PEEK implant is doubtful.[10] PEEK material exhibits limited osteoconductive properties unlike titanium.[11]

Various treatments can be done to improve the bioactivity. They are-

1. Physical treatment.
2. Chemical treatment.
3. Surface coating.
4. Composite preparation.

Physical treatment like plasma modification have been tried by using nitrogen and oxygen plasma, oxygen and argon plasma, ammonia and argon plasma, hydrogen plasma, methane and oxygen plasma which resulted in increased adhesion, proliferation and osteogenic differentiation.[1]

Chemical treatment like wet chemistry and sulfonation, surface coating with titanium, gold, diamond like carbon, titanium oxide and hydroxyapatite have been considered. Hydroxyapatite is most commonly used due to its bioactivity, biocompatibility and osteoconductivity in vivo. Various techniques has been followed for surface coating like deposition of aerosol, electron beam deposition, cold spray technique, radio frequency magnetron sputtering and spin coating. Study was carried out by Devine et al on the bioactivity of titanium coated and uncoated implants and it

was concluded that the titanium implants coated with carbon fibres improved the torque and bone apposition of PEEK screws compared to uncoated implants. Some authors have compared the coating of titanium by physical vapour deposition and vacuum plasma spraying and it was found that the removal torque of vacuum plasma spraying was significantly greater than the uncoated physical vapour deposition screw. Spin coating process has been tried to coat a thin layer of nanoparticles calcium hydroxyapatite on PEEK. Plasma spray etching is another procedure to modify the nanoscale surface of PEEK, in these gases at low pressure are used to introduce nano level surface irregularities and functional group on PEEK. Gas plasma modified implants showed more hydrophilicity and improved differentiation and proliferation of mesenchymal cells on implant surface.[2,11]

Koch et al compared the contact of implant bone in PEEK, titanium and zirconia implants and observed that PEEK implants have the minimum value. As PEEK is bioinert material and therefore the bone apposition potential is inadequate.[12] Studies have been done on PEEK implants coated with hydroxyapatite to increase the cells attachments and favourable results were obtained.[13]

Compression molding technique and melt blending technique are used to increase the bioactivity of PEEK by addition of bioactive materials. The size of bioactive HAp (Hydroxyapatite) ranges from 2 – 4 μm and it has negative impact on the mechanical properties of PEEK. Therefore the nano sized particles are used instead of it. Increased bioactivity, better mechanical properties are some of the advantages of implants made from PEEK nanocomposite. Mainly hydroxy fluorapatite is added as a nano sized particle which has antimicrobial properties against *Streptococcus mutans* and can also improves the osseointegration in vivo. Studies which are performed on animals showed that nano titanium oxide (TiO_2) PEEK has more bioactivity than the pure PEEK. Nanocomposites can also be used in indirect intra coronal and extra coronal restorations. Wang et al reported the additional advantage of being anti-bacterial.

With current researches, it is examined that there is no long term studies with the durability of material on patients. Still more relevant studies are required before it can be used and thus PEEK has not gained attraction clinically.[10]

PEEK ABUTMENTS

Osseointegration of implant is very crucial for the success of implant supported prosthesis. The abutment material should meet all the mechanical, biological and aesthetic properties. Various dental alloys are used for fabrication of abutments such as titanium, gold, zirconia, and ceramics. Most commonly used titanium and its alloy may cause allergic reaction and corrosion in some patients leading to peri implantitis and implant failure. In anterior region where aesthetic is of prime consideration and satisfactory results cannot be obtained because of thin gingival biotype. Zirconia abutments can be used in such cases but it may worn with time and even the mechanical resistance is not so good. The other disadvantages of zirconia are deterioration at low temperature in water and water solutions and transition from a tetragonal phase to monolithic phase. Various in vivo and in vitro studies have shown the use of zirconia and aluminium abutments over full ceramics restorations mainly in single tooth implant. PEEK can be used for manufacturing of implant healing abutments because of its biocompatibility. PEEK abutment can resist chewing force up to 1200 N as it has elastic property it reduces the forces transmitted to the implant. Koutouzis et al[14] conducted a randomised controlled trial and suggested that there is no pronounced difference in the soft tissue inflammation and bone resorption around PEEK and titanium abutments.[15] Even the elastic of modulus is close to the cortical bone hence it diminishes the stress shielding effects and stimulate bone remodelling. Therefore PEEK can be used as an alternative to titanium abutments and implants. Hendrik et al conducted a study on composite resin crowns were it was applied on PEEK and titanium abutment and breaking resistance were compared. Lower resistance was found with crowns applied over PEEK abutment.

PEEK AS REMOVABLE PARTIAL DENTURE FRAMEWORK

With the advancement in technologies dentures can be fabricated by Computer Aided Design and Computer Aided Machines using PEEK material.[15] Tannous et al constructed retentive clasps of denture using PEEK and suggested PEEK has less retentive forces compared to cobalt chromium clasps[16]. Hence lead to evolution of modified PEEK containing 20 % ceramic fillers known as BioPP (Bredent GmBH, Senden, Germany). BioPP material have greater potential as framework material in patients with high aesthetics requirements. There is possibilities of correction, good stability, polish ability and aesthetics which allows BioPP to produce high quality prosthesis.[17] The PEEK clasps and other components of it also eliminate the metallic taste and allergic reactions. It can be easily polished and has low plaque retention. PEEK can also be used for fabrication of braces and hooks because of its white colour and high resistance. PEEK has more colour stability than resins. Study was conducted on the PEEK, polymethyl metha acrylate and composite resin, the comparison of the surface roughness, surface free energy of polishing methods was applied in clinic and laboratory. And it was resulted that as the PEEK is harder material the surface energy and surface roughness was lower compared to other two. It has also been reported for long term use because of its low solubility and sorption properties.

Costa Palau et al in their clinical report fabricated a maxillary obturator for a patient with oronasal defect using PEEK. They found that the PEEK obturator was weightless, biocompatible with good retention and ease of polishing. Aesthetic, retention and patient comfort were greatly enhanced. PEEK Optima is a better alternative to conventional materials for rehabilitation of large maxillofacial defects with obturator prosthesis.[18]

PEEK AS FIXED DENTAL PROSTHESIS

Various resin and metal alloys materials are available for the restoration of implant supported prosthesis. But with due course of time there is higher chance of discolouration and wearing of material which leads to aesthetic situation. Metal alloys can undergo corrosion and can cause allergies.[19] PEEK is biocompatible and can be used because of its excellent properties and is an opaque material, it should be veneered with composites to attain aesthetics. The grey colour of PEEK can be adjusted by adding appropriate amount of pigments in unfilled material. Many methods have been tried to attain better bond strength of PEEK with veneering materials. Surface treatments such as sandblasting, Rocatec procedure, surface etching with sulphuric acid and piranha solution.[20,21] Recently plasma is used to modify the surface which micro etch, removes residues, allows cross linking and activates the surface of PEEK.[20] Surface modification of PEEK have been considered for bonding with different luting agents, multifunctional methacrylate containing resin varnish or air abraded PEEK surfaces produces a promising durable bond to PEEK.[21] Panaiotis et al used modified PEEK for endocrown restoration for a extensively damaged molar and veneered with indirect light polymerized composite resin. And suggested that the elastic modulus of PEEK framework veneered with indirect composite could dampen the occlusal forces protecting tooth structures better than ceramic material.[22] Major advantage of PEEK is it can bind easily with indirect composite polymerised with light. When PEEK is used as temporary abutment high bonding must be required between the composite resin for the formation of emergence profile and gingival shaping. Studies reported that use of Visolink and Signum PEEK can significantly increase the bond between composite resin and PEEK. Taufell et al also suggested the advantages of CAD CAM method compared to the manual coating such as resistance to wear, low coloration, standardization and low monomer content of the veneers.[20]

Considering good abrasion resistance, mechanical attributes and adequate bonding to composites and teeth, PEEK fixed prosthesis would be expected to have a satisfactory survival rate.

PEEK CAD CAM MILLED FIXED DENTAL PROSTHESIS

With the advancement in technologies the restorations can be fabricated chairside in short duration of time by computer aided designing and computer aided manufacturing. The fixed prosthesis fabricated from composite and Poly Methyl Methacrylate (PMMA) have superior mechanical properties than the conventional fixed dental prosthesis. Alternative to PMMA, PEEK material is used for CAD CAM restoration and the three unit fixed partial denture of PEEK showed higher fracture resistance than granular or pellet shaped PEEK dentures. The fracture resistance of the PEEK fixed partial prosthesis fabricated by CAD CAM is highest than the lithium disilicate glass ceramics (950N), alumina (851N), zirconia (981 - 1331N).[23] PEEK also has excellent abrasive properties and is competitive with metal alloys. No clinical studies have compared the abrasion resistance of PEEK and therefore it is not yet clear that PEEK can function efficiently with enamel and dentin. Considering the other properties which are superior to other conventional materials, a PEEK fixed partial denture is expected to have long term survival rate.[24]

CONCLUSIONS

PEEK can be an alternative to metals. PEEK can be used in many instances in prosthodontics such as implants, fixed partial dentures and removable prosthesis due to its excellent physical, mechanical, aesthetic properties and biocompatibility. Though PEEK is already being used as a forerunner material in spine, orthopaedics, the usage of PEEK polymer material in dentistry is yet to gain momentum. This may be because of very few long-term clinical studies which are available. Hence more research is needed on PEEK polymer.

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